

PATENT COOPERATION TREATY

30 Rec'd PCT/PTO

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From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF
RECORD COPY

(PCT Rule 24.2(a))



To:

AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540
JAPON

Date of mailing (day/month/year) 01 April 1996 (01.04.96)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 659390	International application No. PCT/JP96/00637

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

OSAKA GAS COMPANY LIMITED et al (for all designated States except US)
TABATA, Takeshi et al (for US)

International filing date : 14 March 1996 (14.03.96)
Priority date(s) claimed : 17 March 1995 (17.03.95)
18 April 1995 (18.04.95)
31 July 1995 (31.07.95)

Date of receipt of the record copy
by the International Bureau : 29 March 1996 (29.03.96)

List of designated Offices :

National : CA,CN,JP,KR,US

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- ☒ time limits for entry into the national phase;
- ☒ confirmation of precautionary designations;
- ☒ requirements regarding priority documents.

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. (41-22) 740.14.35	Authorized officer: Y. Hamano Telephone No. (41-22) 730.91.11
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INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the "national phase" must be entered before each of the designated Offices indicated in the Notification of Receipt of Record Copy (Form PCT/IB/301) by paying national fees and furnishing translations, as prescribed by the applicable national laws.

The time limit for performing these procedural acts is **20 MONTHS** from the priority date or, for those designated States which the applicant elects in a demand for international preliminary examination or in a later election, **30 MONTHS** from the priority date, provided that the election is made before the expiry of 19 months from the priority date. Some designated (or elected) Offices have fixed time limits which expire even later than 20 or 30 months from the priority date. In other Offices an extension of time or grace period, in some cases upon payment of an additional fee, is available.

In addition to these procedural acts, the applicant may also have to comply with other special requirements applicable in certain Offices. **It is the applicant's responsibility** to ensure that the necessary steps to enter the national phase are taken in a timely fashion. Most designated Offices do not issue reminders to applicants in connection with the entry into the national phase.

For detailed information about the procedural acts to be performed to enter the national phase before each designated Office, the applicable time limits and possible extensions of time or grace periods, and any other requirements, see the relevant Chapters of Volume II of the PCT Applicant's Guide. Information about the requirements for filing a demand for international preliminary examination is set out in Chapter IX of Volume I of the PCT Applicant's Guide.

Note that since ES and GR are not bound by PCT Chapter II (which provides for the international preliminary examination procedure), those States cannot be elected in a demand for international preliminary examination. In the case of the designation of ES for a national patent, the applicant must thus always enter the national phase before the national Office of that State before the expiry of 20 months from the priority date. In the case of the designation of ES or GR for a European patent, however, the 31-month time limit applies in respect of those designations if at least one other State designated for a European patent is also elected within the 19-month period.*

Note also that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

- * CH and LI became bound by PCT Chapter II on 1 September 1995. Therefore, CH and LI may be elected in a demand or a later election filed on or after that date, regardless of the filing date of the international application. (See 2nd paragraph above.)

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date. If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with an indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents the following is recalled.

Where the priority of an earlier national (i.e., national or regional) application is claimed, the applicant must submit a copy of the said national application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date (Rule 17.1).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such a request must be made before the expiration of the 16-month time limit.

It is recalled that, where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

If the priority document concerned is not submitted to the International Bureau before the expiration of the 16-month time limit, or if the request to the receiving Office to transmit the priority document has not been made (and the corresponding fee, if any, paid) before the expiration of this time limit, any designated State may disregard the priority claim.

PATENT COOPERATION TREATY

PCT

NOTIFICATION CONCERNING
SUBMISSION OF PRIORITY DOCUMENTS

(PCT Administrative Instructions, Section 411)



From the INTERNATIONAL BUREAU

To:

AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540
JAPON

Date of mailing (day/month/year) 25 June 1996 (25.06.96)		IMPORTANT NOTIFICATION	
Applicant's or agent's file reference 659390			
International application No. PCT/JP96/00637	International filing date (day/month/year) 14 March 1996 (14.03.96)	Priority date (day/month/year) 17 March 1995 (17.03.95)	
Applicant OSAKA GAS COMPANY LIMITED et al			

The applicant is hereby notified of the date of receipt by the International Bureau of the priority document(s) relating to the following application(s):

<u>Priority application No:</u>	<u>Priority date:</u>	<u>Priority country:</u>	<u>Date of receipt of priority document:</u>
7/86259	17 Mar 1995 (17.03.95)	JP	21 Jun 1996 (21.06.96)
7/117874	18 Apr 1995 (18.04.95)	JP	21 Jun 1996 (21.06.96)
7/194657	31 Jul 1995 (31.07.95)	JP	21 Jun 1996 (21.06.96)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

T. Inoue

Telephone No.: (41-22) 730.91.11

PATENT COOPERATION TREATY

PCT



From the INTERNATIONAL BUREAU

To:

NOTICE INFORMING THE APPLICANT OF THE
COMMUNICATION OF THE INTERNATIONAL
APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

AOYAMA, Tamotsu
Aoyama & Partners
IMP Building
3-7, Shiromi 1-chome
Chuo-ku, Osaka-shi
Osaka 540
JAPON

Date of mailing (day/month/year) 26 September 1996 (26.09.96)		IMPORTANT NOTICE	
Applicant's or agent's file reference 659390			
International application No. PCT/JP96/00637	International filing date (day/month/year) 14 March 1996 (14.03.96)	Priority date (day/month/year) 17 March 1995 (17.03.95)	
Applicant OSAKA GAS COMPANY LIMITED et al			

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
CA,CN,JP,KR,US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
None

The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
26 September 1996 (26.09.96) under No. WO 96/29140

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a **demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. (41-22) 740.14.35	Authorized officer J. Zahra Telephone No. (41-22) 730.91.11
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PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

PCT

International Filing Date

14.03.96

受領印

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference
(if desired) (12 characters maximum)

659390

Box No. I TITLE OF INVENTION
Nitrogen Oxide-Reducing catalyst and Process for Reducing Nitrogen Oxides in Exhaust Gas

Box No. II APPLICANT

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

Osaka Gas Company Limited

1-2, Hiranomachi 4-chome, Chuo-ku,
Osaka-shi, Osaka 541 JAPAN

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State (i.e. country) of nationality:

Japan

State (i.e. country) of residence:

Japan

This person is applicant for the purposes of:

☐ all designated States

☒ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

Eniricerche S. p. A.

Via F. Maritano 26,
20097 San Donato Milanese, ITALY

This person is:

☒ applicant only

☐ applicant and inventor

☐ inventor only (If this check-box is marked, do not fill in below.)

State (i.e. country) of nationality:

Italy

State (i.e. country) of residence:

Italy

This person is applicant for the purposes of:

☐ all designated States

☒ all designated States except the United States of America

☐ the United States of America only

☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:

☒ agent

☐ common representative

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

6214 Patent Attorney AOYAMA Tamotsu
7821 Patent Attorney KAIZAKI Eiji
10311 Patent Attorney KITAHARA Yasuhiro
(A311)
Aoyama & Partners, IMP Building, 3-7,
Shiromi 1-chome, Chuo-ku, Osaka-shi,
Osaka 540 JAPAN

Telephone No.

06-949-1261

Facsimile No.

06-949-0361

Teleprinter No.

MIZAOY J63716

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. **FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS***If none of the following sub-boxes is used, this sheet is not to be included in the request.*Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

TABATA Takeshi

9-28-102, Sonenishimachi 3-chome,
Toyonaka-shi, Osaka 561 JAPAN

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only *(If this check-box is marked, do not fill in below.)*State (i.e. country) of nationality:
JapanState (i.e. country) of residence:
JapanThis person is applicant
for the purposes of:☐ all designated
States☐ all designated States except
the United States of America☒ the United States
of America only☐ the States indicated in
the Supplemental BoxName and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

KOKITSU Mikako

2-20-302, Okakamincho 4-chome,
Toyonaka-shi, Osaka 560 JAPAN

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only *(If this check-box is marked, do not fill in below.)*State (i.e. country) of nationality:
JapanState (i.e. country) of residence:
JapanThis person is applicant
for the purposes of:☐ all designated
States☐ all designated States except
the United States of America☒ the United States
of America only☐ the States indicated in
the Supplemental BoxName and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

OKADA Osamu

17-7, Ohnodai 4-chome, Osakasayama-shi,
Osaka 589 JAPAN

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only *(If this check-box is marked, do not fill in below.)*State (i.e. country) of nationality:
JapanState (i.e. country) of residence:
JapanThis person is applicant
for the purposes of:☐ all designated
States☐ all designated States except
the United States of America☒ the United States
of America only☐ the States indicated in
the Supplemental BoxName and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

OHTSUKA Hirofumi

4-23, Takezonocho, Ashiya-shi,
Hyogo 659 JAPAN

This person is:

☐ applicant only☒ applicant and inventor☐ inventor only *(If this check-box is marked, do not fill in below.)*State (i.e. country) of nationality:
JapanState (i.e. country) of residence:
JapanThis person is applicant
for the purposes of:☐ all designated
States☐ all designated States except
the United States of America☒ the United States
of America only☐ the States indicated in
the Supplemental Box☒ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Continuation of Box No. FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

BELLUSSI, Giuseppe
Via A. Scotto 44,
29100 Piacenza, ITALY

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (i.e. country) of nationality:
ItalyState (i.e. country) of residence:
Italy

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

SABATINO, Luigina Maria Flora
Via Morandi 2/B,
20097 San Donato Milanese, ITALY

This person is:

- ☐ applicant only
☒ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (i.e. country) of nationality:
ItalyState (i.e. country) of residence:
Italy

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (i.e. country) of nationality:

State (i.e. country) of residence:

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

This person is:

- ☐ applicant only
☐ applicant and inventor
☐ inventor only (If this check-box is marked, do not fill in below.)

State (i.e. country) of nationality:

State (i.e. country) of residence:

This person is applicant for the purposes of:

- ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) (mark the applicable check-boxes; at least one must be marked):

Regional Patent

- ☐ AP ARIPO Patent: KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SZ Swaziland, UG Uganda, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☐ EA Eurasian Patent: AZ Azerbaijan, BY Belarus, KZ Kazakstan, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☐ EP European Patent: AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, DE Germany, DK Denmark, ES Spain, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☐ OA OAPI Patent: BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT (if other kind of protection or treatment desired, specify on dotted line)

National Patent (if other kind of protection or treatment desired, specify on dotted line):

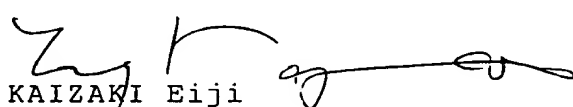
- | | |
|---|---|
| <input type="checkbox"/> AL Albania | <input type="checkbox"/> MD Republic of Moldova |
| <input type="checkbox"/> AM Armenia | <input type="checkbox"/> MG Madagascar |
| <input type="checkbox"/> AT Austria | <input type="checkbox"/> MK The former Yugoslav Republic of Macedonia |
| <input type="checkbox"/> AU Australia | <input type="checkbox"/> MN Mongolia |
| <input type="checkbox"/> AZ Azerbaijan | <input type="checkbox"/> MW Malawi |
| <input type="checkbox"/> BB Barbados | <input type="checkbox"/> MX Mexico |
| <input type="checkbox"/> BG Bulgaria | <input type="checkbox"/> NO Norway |
| <input type="checkbox"/> BR Brazil | <input type="checkbox"/> NZ New Zealand |
| <input type="checkbox"/> BY Belarus | <input type="checkbox"/> PL Poland |
| <input checked="" type="checkbox"/> CA Canada | <input type="checkbox"/> PT Portugal |
| <input type="checkbox"/> CH and LI Switzerland and Liechtenstein | <input type="checkbox"/> RO Romania |
| <input checked="" type="checkbox"/> CN China | <input type="checkbox"/> RU Russian Federation |
| <input type="checkbox"/> CZ Czech Republic | <input type="checkbox"/> SD Sudan |
| <input type="checkbox"/> DE Germany | <input type="checkbox"/> SE Sweden |
| <input type="checkbox"/> DK Denmark | <input type="checkbox"/> SG Singapore |
| <input type="checkbox"/> EE Estonia | <input type="checkbox"/> SI Slovenia |
| <input type="checkbox"/> ES Spain | <input type="checkbox"/> SK Slovakia |
| <input type="checkbox"/> FI Finland | <input type="checkbox"/> TJ Tajikistan |
| <input type="checkbox"/> GB United Kingdom | <input type="checkbox"/> TM Turkmenistan |
| <input type="checkbox"/> GE Georgia | <input type="checkbox"/> TR Turkey |
| <input type="checkbox"/> HU Hungary | <input type="checkbox"/> TT Trinidad and Tobago |
| <input type="checkbox"/> IS Iceland | <input type="checkbox"/> UA Ukraine |
| <input checked="" type="checkbox"/> JP Japan | <input type="checkbox"/> UG Uganda |
| <input type="checkbox"/> KE Kenya | <input checked="" type="checkbox"/> US United States of America |
| <input type="checkbox"/> KG Kyrgyzstan | <input type="checkbox"/> UZ Uzbekistan |
| <input type="checkbox"/> KP Democratic People's Republic of Korea | <input type="checkbox"/> VN Viet Nam |
| <input checked="" type="checkbox"/> KR Republic of Korea | |
| <input type="checkbox"/> KZ Kazakstan | |
| <input type="checkbox"/> LK Sri Lanka | |
| <input type="checkbox"/> LR Liberia | |
| <input type="checkbox"/> LS Lesotho | |
| <input type="checkbox"/> LT Lithuania | |
| <input type="checkbox"/> LU Luxembourg | |
| <input type="checkbox"/> LV Latvia | |

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

- ☐
- ☐
- ☐
- ☐

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of

The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. (Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)

Box No. VI PRIORITY CLAIM		Further priority claims are indicated in the Supplemental Box <input type="checkbox"/>	
The priority of the following earlier application(s) is hereby claimed:			
Country (in which, or for which, the application was filed)	Filing Date (day/month/year)	Application No.	Office of filing (only for regional or international application)
item (1) JP	17.03.95	Patent Application 7-86259	
item (2) JP	18.04.95	Patent Application 7-117874	
item (3) JP	31.07.95	Patent Application 7-194657	
Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required): <input type="checkbox"/> The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s) : _____			
Box No. VII INTERNATIONAL SEARCHING AUTHORITY			
Choice of International Searching Authority (ISA) (If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used): ISA / EP			
Earlier search Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request. Country (or regional Office): _____ Date (day/month/year): _____ Number: _____			
Box No. VIII CHECK LIST			
This international application contains the following number of sheets: 1. request : 5 sheets 2. description : 30 sheets 3. claims : 3 sheets 4. abstract : 1 sheets 5. drawings : 4 sheets Total : 43 sheets		This international application is accompanied by the item(s) marked below: 1. <input type="checkbox"/> separate signed power of attorney 2. <input type="checkbox"/> copy of general power of attorney 3. <input type="checkbox"/> statement explaining lack of signature 4. <input type="checkbox"/> priority document(s) identified in Box No. VI as item(s): _____ 5. <input type="checkbox"/> fee calculation sheet 6. <input type="checkbox"/> separate indications concerning deposited microorganisms 7. <input type="checkbox"/> nucleotide and/or amino acid sequence listing (diskette) 8. <input type="checkbox"/> other (specify): _____	
Figure No. _____ of the drawings (if any) should accompany the abstract when it is published.			
Box No. IX SIGNATURE OF APPLICANT OR AGENT			
Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).			
 KAIZAKI Eiji			

For receiving Office use only	
1. Date of actual receipt of the purported international application: _____ 3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application: _____ 4. Date of timely receipt of the required corrections under PCT Article 11(2): _____ 5. International Searching Authority specified by the applicant: ISA /	2. Drawings: <input type="checkbox"/> received: <input type="checkbox"/> not received: 6. <input type="checkbox"/> Transmittal of search copy delayed until search fee is paid

For International Bureau use only	
Date of receipt of the record copy by the International Bureau: _____	



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B01D 53/86, 53/94, B01J 29/46		A1	(11) International Publication Number: WO 96/29140
			(43) International Publication Date: 26 September 1996 (26.09.96)
(21) International Application Number: PCT/JP96/00637		(74) Agents: AOYAMA, Tamotsu et al.; Aoyama & Partners, IMP Building, 3-7, Shiromi 1-chome, Chuo-ku, Osaka-shi, Osaka 540 (JP).	
(22) International Filing Date: 14 March 1996 (14.03.96)			
(30) Priority Data:		(81) Designated States: CA, CN, JP, KR, US.	
7/86259 17 March 1995 (17.03.95) JP		Published With international search report.	
7/117874 18 April 1995 (18.04.95) JP			
7/194657 31 July 1995 (31.07.95) JP			
(71) Applicants (for all designated States except US): OSAKA GAS COMPANY LIMITED [JP/JP]; 1-2, Hiranomachi 4-chome, Chuo-ku, Osaka-shi, Osaka 541 (JP). ENIRICERCHES.P.A. [IT/IT]; Via F. Maritano, 26, I-20097 San Donato Milanese (IT).			
(72) Inventors; and			
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(54) Title: NITROGEN OXIDE-REDUCING CATALYST AND PROCESS FOR REDUCING NITROGEN OXIDES IN EXHAUST GAS			
(57) Abstract			
<p>The present invention relates to a catalyst for reducing nitrogen oxides (NOx) in exhaust gas, comprising crystalline metallosilicate ion-exchanged with Co, and channels of particular structure formed in the crystalline metallosilicate, and to a NOx reduction process using said catalyst; said catalyst having a high selectivity for NOx reduction and a high NOx reduction activity even at low temperatures.</p>			

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INTERNATIONAL SEARCH REPORT

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B. FIELDS SEARCHED

 Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	EP,A,0 652 040 (ENIRICERCH & OSAKA GAS) 10 May 1995 see page 3, line 11 - page 4, line 15; claims; examples ---	1-5,9, 10,13
X	WO,A,94 01365 (MOBIL OIL CORPORATION) 20 January 1994 see claims	1,3,4,9
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X	US,A,5 149 512 (AIR PRODUCTS AND CHEMICALS) 22 September 1992 cited in the application see claims 1-6; table 2 ---	1,3,4,9, 13
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 149 512 (LI YUEJIN ET AL) 22 September 1992 see column 7, line 5 - line 54 see column 11, line 53 - line 68; claims 1-35; tables 1,2 ---	1,3-12
X	EP,A,0 603 900 (TOSOH CORP) 29 June 1994 see page 2, line 50 - line 58 see page 3, line 34 - line 55; claims 1-7; examples 4,8,9,19-21 ---	1,2,4-6, 8-12
A	GB,A,2 238 784 (INST OF RESEARCH AND INNOVATIO) 12 June 1991 see claims 1-4; tables 2-4 --- -/--	1-12

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(21) International Application Number: PCT/JP96/00637 (22) International Filing Date: 14 March 1996 (14.03.96) (30) Priority Data: 7/86259 17 March 1995 (17.03.95) JP 7/117874 18 April 1995 (18.04.95) JP 7/194657 31 July 1995 (31.07.95) JP (71) Applicants (for all designated States except US): OSAKA GAS COMPANY LIMITED [JP/JP]; 1-2, Hiranomachi 4-chome, Chuo-ku, Osaka-shi, Osaka 541 (JP). ENIRICERCHES P.A. [IT/IT]; Via F. Maritano, 26, I-20097 San Donato Milanese (IT). (72) Inventors; and (75) Inventors/Applicants (for US only): TABATA, Takeshi [JP/JP]; 9-28-102, Sonenishimachi 3-chome, Toyonaka-shi, Osaka 561 (JP). KOKITSU, Mikako [JP/JP]; 2-20-302, Okakamincho 4-chome, Toyonaka-shi, Osaka 560 (JP). OKADA, Osamu [JP/JP]; 17-7, Ohnodai 4-chome, Osakasayama-shi, Osaka 589 (JP). OHTSUKA, Hirofumi [JP/JP]; 4-23, Takezonocho, Ashiya-shi, Hyogo 659 (JP). BELLUSSI, Giuseppe [IT/IT]; Via A. Scotto, 44, I-29100 Piacenza (IT). SABATINO, Luigina, Maria, Flora [IT/IT]; Via Morandi, 2/B, I-20097 San Donato Milanese (IT).		(74) Agents: AOYAMA, Tamotsu et al.; Aoyama & Partners, IMP Building, 3-7, Shiromi 1-chome, Chuo-ku, Osaka-shi, Osaka 540 (JP). (81) Designated States: CA, CN, JP, KR, US. Published <i>With international search report.</i>
(54) Title: NITROGEN OXIDE-REDUCING CATALYST AND PROCESS FOR REDUCING NITROGEN OXIDES IN EXHAUST GAS		
(57) Abstract <p>The present invention relates to a catalyst for reducing nitrogen oxides (NOx) in exhaust gas, comprising crystalline metallosilicate ion-exchanged with Co, and channels of particular structure formed in the crystalline metallosilicate, and to a NOx reduction process using said catalyst; said catalyst having a high selectivity for NOx reduction and a high NOx reduction activity even at low temperatures.</p>		

DESCRIPTION

Nitrogen Oxide-Reducing catalyst and
Process for Reducing Nitrogen Oxides in Exhaust Gas

5

Technical Field

The present invention relates to a catalyst for reducing nitrogen oxides in exhaust gas, more particularly to a catalyst for reducing nitrogen oxides by using hydrocarbon in exhaust gas containing an excessive amount of oxygen, and to a process for reducing nitrogen oxides in exhaust gas, more particularly in exhaust gases containing hydrocarbon and an excessive amount of oxygen.

Background Art

As a process for removing nitrogen oxides (hereinafter referred to as NO_x) from oxygen-rich exhaust gas, ammonia denitration method has been put to practical use. However, this process cannot be applied to small combustors for the following two reasons: firstly, this process requires a storage of an ammonia source, and secondly, slip of excess ammonia causes a secondary environmental pollution problem. It has been found recently, as is disclosed in Japanese Patent application laid-open No. Sho 63-100919, that NO_x can be selectively reduced with hydrocarbon on a zeolite catalyst ion-exchanged with a metal like Cu.

Problems to Be Solved by the Invention

However, if hydrocarbons with four or smaller number of

carbons are used as the reducing agent, this catalyst has a low selectivity (molar ratio of the hydrocarbons used for NO_x reduction to the consumed hydrocarbons) in the presence of water vapor which always exists in general exhaust gases, resulting in
5 insufficient NO_x conversion.

Armor, et al. have reported that NO_x can be reduced selectively by methane on Co ion-exchanged ZSM-5 (MFI zeolite) (in "Applied Catalysis B: Environmental," Vol. 1, p. L31). Co ion-exchanged mordenite is disclosed, as a selective NO_x reducing
10 catalyst, in U.S. Patent Publication No. 5149512. However, these publications give mere examples of catalysts that show the catalytic activity under the condition without water vapor. It has been known that these catalysts are also deactivated to the level insufficient for practical use in the presence of water
15 vapor. These problems of the conventional catalysts urged search for an improved catalyst which is active even in the presence of water vapor.

To solve the above-mentioned problems, the present invention is to provide a NO_x reducing catalyst with high durability which
20 is capable of removing NO_x from exhaust gas that contains relatively lower hydrocarbon alone as exhausted from natural gas combustion, and of providing sufficiently high activity at low temperatures even in exhaust gas containing water vapor, sulfur oxides (hereinafter referred to as SO_x), etc., and to provide a
25 NO_x reduction process using this catalyst, as well as to provide a NO_x reducing catalyst on which methane can be effectively utilized as a reductant, and a NO_x reduction process using this

catalyst.

Disclosure of Invention

To solve the above mentioned problems, the inventors intensively studied catalysts made of crystalline metallosilicate loaded, by ion exchange with Co. As a result, the inventors found that Co ions dispersed in channels in the crystalline metallosilicate serve as active sites effective in the reaction for selective catalytic reduction of NO_x using hydrocarbons consisting of about two to five carbons as the reducing agent, and that active sites deep in the channels also contribute to the reaction, unlike the case with a zeolite catalyst loaded with Cu or precious metals. Specifically, in the case of the zeolite catalyst loaded with Cu or precious metals, since the metal has high oxidation activity, the reaction for reduction is terminated on the metals or metal ions existing on the zeolite particle surfaces. Metal ions existing deep in the channels cannot contribute to the reaction. By contrast, the crystalline metallosilicate catalyst loaded with Co is expected to provide high selectivity for NO_x reduction, due to low oxidation activity of Co. However, since the reaction for NO_x reduction on this catalyst is slow, unreacted reactants enter deep in the channels, thus causing reaction even on Co ions existing deep in the channels. The catalytic activity may be improved by increasing the concentration of these active sites on the particle surfaces of the support. However, it is found that, if Co ions are too close to one another, an oxide cluster that can activate oxygen, such as Co₃O₄, will be formed, so that the hydrocarbon oxidation

activity is enhanced, resulting in lower selectivity of the catalyst and smaller number of active sites.

At low temperatures, the Co-ZSM-5 or similar catalyst does not provide high activity for selective catalytic reduction of NOx by lower hydrocarbons in an atmosphere containing water vapor and SOx. The inventors found that this phenomenon is attributed to insufficient diffusion of reactants and reaction products. Specifically, the water vapor and SOx contained in the atmosphere prevent diffusion of reactants and reaction products, so that active sites deep in the channels are not used effectively. The inventors also found that, to effectively use the active sites present deep in the channels, the channels must be not only large in diameter but also straight, and that the channels of such structure must be oriented in at least two different dimensional directions and must communicate with each other, forming bypasses.

The present invention has been made based on these findings. The catalyst according to the present invention contains crystalline metallosilicate ion-exchanged with Co to provide active sites, the crystalline metallosilicate having straight channels of oxygen 8-ring or larger section, directed in at least two different dimensional directions, said straight channels communicating with each other via oxygen 8-ring or larger micropores, the straight channels in at least one direction having oxygen 10-ring or larger section. The NOx reduction process according to the present invention comprises the use of the above-mentioned catalyst.

The crystalline metallosilicate constituting the catalyst of this invention has straight channels of oxygen 8-ring or larger section, which are oriented in at least two different dimensional directions. The straight channels communicate with each other via oxygen 8-ring or larger micropores. The channels in at least one direction have oxygen 10-ring or larger section. To prevent water vapor and SO_x from hampering the diffusion of reactants and reaction products, the straight channels are required to have bypasses. The metallosilicate, like MOR type, in which the straight channels are formed in only one direction, is not applicable, because, if the channels are clogged with SO_x etc., reactants can never reach active sites existing in the deeper part of the clogged channels.

The diffusion rate in the channels differs widely depending on whether the channels are straight or bent. It is considered that diffusion effective for reduction of NO_x in exhaust gas can occur almost only in straight channels. In the case of MFI type metallosilicate in which straight channels are formed in only one direction, if the channels are blocked, it takes so long time for reactants to make a detour to reach active sites. Accordingly, it is necessary that straight channels be formed in at least two different directions, communicating with each other.

If the section of each straight channel is smaller than oxygen 8-ring, reactants, such as NO_x and hydrocarbons, cannot be diffused into the channels. The larger is the section of each straight channel, the better, as long as the crystalline metallosilicate has sufficient thermostability. The crystalline

metallo silicate having the above-mentioned channel structure includes the types of AFR, AFS, AFY, BEA, BOG, BPH, DAC, FER, GME, HEU, LTL, MEL, MFS or OFF, preferably, BEA, BOG or MEL type in which channels are large in diameters. More preferable type is BEA or MEL because they can be synthesized easily as a product of high purity. The most preferable form is BEA which has straight channels of oxygen 12-ring section in two different dimensional directions, the channels communicating with each other via oxygen 12-ring micropores.

In addition to the above-mentioned channel structure, the crystalline metallo silicate used for the present invention is required to have ion exchange capacity. Crystalline aluminosilicate which is zeolite in a narrow sense, silico-aluminophosphate (SAPO), gallosilicate, etc. are examples of crystalline metallo silicate with ion exchange capacity. Crystalline metallo silicate where silicon is partly replaced with titanium etc. may be used. Although the crystalline metallo silicate of the present invention is not limited to these insofar as it has stable ion exchange capacity, Aluminosilicate is the most preferable in view of the thermostability of crystal and the controllability of ion exchange capacity.

Ion exchange capacity is important because it directly determines the number of active sites. For aluminosilicate, the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio (molar ratio) is a measure for the ion exchange capacity. When this ratio is higher than 100, the aluminosilicate has insufficient ion exchange capacity so is in short of active sites. When this ratio is lower than 10, on the

other hand, the aluminosilicate increases in hydrophilicity, causing that water vapor hampers reaction for NOx reduction. In addition, excessive number of cations fills the channels, narrowing the space, thus impairing the diffusibility.

5 Therefore, the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of aluminosilicate should be preferably between 10 and 100. For any applicable crystalline metallosilicate other than aluminosilicate, the total number of framework atoms (main element of oxide) the total number of per exchangeable cations calculated as divalent cation should also be
10 of a value corresponding to the above-mentioned ratio. The $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio for stable crystalline metallosilicate is generally fixed for each type of crystalline metallosilicate support. The preferable $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of BEA aluminosilicate between 10 and 50. The one of MEL being preferably between 20 and
15 100.

The production process of the crystalline metallosilicate used for the present invention is not limited as far as the crystalline metallosilicate has ion exchange capacity and straight channels of oxygen 8-ring or larger section, directed in
20 at least two different dimensional directions, said straight channels communicating with each other via oxygen 8-ring or larger micropores, the straight channels in at least one direction having oxygen 10-ring or larger section. The crystalline metallosilicate of the above-mentioned structure can
25 be produced, for example, by ordinary hydrothermal synthesis using a template. MEL aluminosilicate can be synthesized by the method disclosed in the U.S. Patent No. 3,709,979, and BEA

aluminosilicate by the method disclosed in the U.S. Patent No. 3,308,069.

Additionally, the average diameter of the primary particles of the crystalline metallosilicate is preferably between 0.01 μm and 0.2 μm , more preferably, between 0.03 μm and 0.1 μm , since the advantage of the crystalline metallosilicate for high diffusion is reduced when the primary particle size is too large. Even if the average diameter of the primary particle is smaller than this lower limit, there is no problem in the durability of the catalyst as far as the catalyst is used under preferable conditions of the present invention. However, the macropore generated between primary particles become too small when the diameter of the primary particles is too small, therefore, the average diameter of the primary particles is preferably at least 0.01 μm . The crystalline metallosilicate having such a particle size can be prepared by the methods disclosed in U.S. Patent No. 3,709,979 and U.S. Patent No. 3,308,069. During the reaction process, higher reactant concentrations, lower pH, higher temperature, more frequent agitation, and shorter reaction time than ordinary synthesis conditions lead to decrease the size of the primary particles of the crystalline.

Another catalyst of the present invention includes BEA zeolite in which part of Si is substituted by Ti, and/or part of Al by B. The BEA zeolite substituted by Ti and/or B can be manufactured from mixture containing Ti source and/or B source, by the ordinary hydrothermal synthesis method using a template. B-substituted BEA zeolite can be manufactured, for example, by

the process disclosed in U.S. Patent No. 5,110,570, and Ti-substituted one by the process disclosed in Spanish Patent No. 2,037,596.

Specifically, B-substituted BEA zeolite can be obtained by
5 adding B source, such as boric acid, borate or trialkyl-borate, to the mixture of Si source, such as silica sol or sodium silicate, and Al source, such as aluminum nitrate, aluminum sulfate or sodium aluminate; mixing them with template such as N-tetraalkylammonium salt, alkali such as sodium hydrate or
10 ammonia, and water; allowing the mixture to react for 2 to 7 days in an autoclave at 90 to 180 °C; filtrating and washing the resultant solid with water; drying it at 80 to 200 °C; and calcining it for 1 hour to 2 days in air at 400 to 700 °C.

Ti-substituted BEA zeolite can be manufactured by the same
15 method as for B-substituted BEA zeolite, except that Ti source, such as halide including titanium chloride, or alkoxide including titanium isopropoxide and titanium tetraethoxide, is added in place of B source to the mixture of Al and Si sources. The duration of reaction in the autoclave may be increased as
20 necessary.

Whether or not the resultant zeolite substituted by Ti and/or B has BEA crystalline structure can easily be determined by X-ray diffraction analysis.

It is preferable that Ti-substituted BEA zeolite should have
25 an $\text{SiO}_2/\text{TiO}_2$ ratio (molar ratio) of 20 to 200. With an $\text{SiO}_2/\text{TiO}_2$ ratio lower than 20, the crystallinity of zeolite is deteriorated, and the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio cannot be raised. With an

SiO₂/TiO₂ ratio higher than 200, on the other hand, the effect of Ti substitution is lost. For the same reason, the SiO₂/B₂O₃ ratio (molar ratio) of B-substituted BEA zeolite should preferably be between 20 and 500.

5 The catalyst of the present invention comprises the above-mentioned crystalline metallosilicate loaded with at least Co by ion exchange. The ion exchange may be carried out by an ordinary method. For example, proton-, sodium- or ammonium-form metallosilicate is suspended in an aqueous solution in which the
10 water-soluble salt of Co is dissolved by a quantity equivalent to, or somewhat larger than, the ion exchange capacity, keeping temperature between room temperature and about 80 °C, to allow ion exchange to take place for an hour to about three days. The resultant product is then washed with water, dried and calcined
15 at temperatures between 400 °C and 750 °C. Since the crystalline metallosilicate has a channel structure suitable for diffusion, ion exchange takes place relatively easily. Therefore, it is more preferable to carry out the ion exchange in aqueous solution of a lower concentration and at a lower temperature, because such
20 conditions allow Co ions to be loaded completely on ion-exchange sites without aggregation.

 Preferable metal loading amount is from 40% to 120% in terms of ion exchange rate. The ion exchange rate is the percentage of the sum of the products of the molar number of loaded metal
25 multiplied by the valence of the metal ions, to the ion exchange capacity obtained by summing up products of the molar number of exchangeable cations multiplied by the valence of the cations. If

the ion exchange rate is lower than the above-mentioned preferable range, the activity of the catalyst will be insufficient. Ion exchange rate higher than this range is not desirable either: metal ions not only fill the straight channels, narrowing the passage for reactants, but also can be aggregated. For boron-substituted BEA zeolite and titanium-substituted BEA zeolite, desirable range of Co loading is 0.2 to 0.6 in terms of Co/Al ratio.

The catalyst of the present invention may contain alkaline earth metal as promoter, and binder, etc. The catalyst of the present invention may be formed into a pellet or honeycomb form, or may be wash-coated on a refractory honeycomb support. Since the catalyst of the present invention uses crystalline metallosilicate support on which metal ions having low oxidation activity can be loaded with high dispersion, high selectivity of NO_x reduction can be obtained. In addition, this metallosilicate has a channel structure suitable for diffusion, therefore, even in an actual exhaust gas atmosphere containing water vapor and SO_x, reactants can reach the active sites of metal ions deep in the channels, resulting high NO_x reduction activity. Thus, the catalyst of the present invention has high activity at low temperatures and maintains high selectivity even at high temperatures, which leads to high NO_x conversion in a wide range of temperatures. Furthermore, since many bypasses allowing high diffusion are formed in the crystalline metallosilicate in case of possible partial clogging of the channels, the catalyst of the present invention has high durability. Besides, using

boron-substituted zeolite, NO_x is selectively reduced by methane in the presence of water vapor.

The NO_x reduction process of the present invention is to selectively reduce NO_x in exhaust gas containing hydrocarbons and an excessive amount of oxygen, using hydrocarbons consisting of two or more carbons on a catalyst. The process according to the present invention uses the catalyst obtained by the method described above, specifically the catalyst which contains crystalline metallosilicate ion-exchanged with Co, said crystalline metallosilicate having straight channels of oxygen 8-ring or larger section, oriented in at least two different dimensional directions and communicating with each other via oxygen 8-ring or larger micropores, the straight channels in at least one direction having oxygen 10-ring or larger section.

Another NO_x reduction process of the present invention uses the catalyst comprising BEA zeolite in which part of Si is substituted by Ti, and/or part of Al by B, and which is ion-exchanged with Co to have a Co/Al ratio between 0.2 and 0.6.

The NO_x reduction process of this invention comprises allowing the above-mentioned catalyst to contact exhaust gas containing NO_x, hydrocarbons and an excessive amount of oxygen. The condition for this reduction process is not limited if the process uses the above-mentioned catalyst. Specifically, the catalyst used in the NO_x reduction process of the present invention is required to contain crystalline metallosilicate ion-exchanged with Co, the crystalline metallosilicate having straight channels of oxygen 8-ring or larger section, oriented in

at least two different dimensional directions, said straight channels communicating with each other via oxygen 8-ring or larger micropores, the straight channels in at least one direction being oxygen 10-ring or larger in section. According to the present invention the process is operated at temperature between 300 °C and 600 °C, preferably between 350 °C and 500 °C, and with a gaseous hourly space velocity (GHSV) between 2,000 and 100,000, preferably between 5,000 and 30,000. Operating temperature lower than 300 °C would result in low catalytic activity, and that higher than 600 °C would cause early deterioration of the catalyst. The GHSV lower than 2,000 would result in high pressure loss in the catalyst bed, and that higher than 100,000 would result in poor NO_x conversion.

The hydrocarbons consisting of two or more carbons used in the present invention refer to a wide variety of hydrocarbons, including olefins such as ethylene, and paraffins such as propane. Preferably, they should be aliphatic hydrocarbons containing two to five carbons. Aromatic hydrocarbons are not preferable since the catalyst of the present invention has low activity for hydrocarbon oxidation. With aliphatic hydrocarbons containing about six or more carbons, the advantageous features of the present invention cannot be utilized since the diffusion rate of the hydrocarbons is low.

On the other hand, methane can be effectively utilized according to another process of the present invention in which a catalyst obtained from boron substituted BEA zeolite is used.

The NO_x reduction process of this invention is not limited

in the NOx concentration of exhaust gas. The hydrocarbon concentration in terms of methane (THC) required for reduction of NOx is, normally, from 1/2 to 10 times the NOx concentration. That is, the hydrocarbon concentration required for reduction of 10 to 5,000 ppm NOx is 5 ppm to 5%. If hydrocarbon content in exhaust gas is not sufficient, an appropriate amount of hydrocarbon may be added to the exhaust gas to attain desired NOx conversion. Since the NOx reduction process of the present invention uses the catalyst which allows easy diffusion in the channels, high NOx conversion can be obtained even at a low NOx concentration which is unfavorable to diffusion. Another NOx reduction process of the present invention uses a catalyst based on BEA zeolite which enables high reactant diffusion. In addition, according to process of the present invention, hydrocarbon activation and NOx reduction activity at low temperature are enhanced, due to the effect of substitution by Ti and/or B. With B-substituted catalyst in particular, it is possible to reduce NOx effectively using methane even in the presence of water vapor.

If the oxygen concentration in exhaust gas is excessively low, oxidation of NO, which is the first stage of reaction, does not occur. The oxygen concentration should preferably be 0.5% or higher, more preferably 3% or higher. Although there is no upper limit of oxygen concentration, oxygen concentration higher than that of air is not preferable since unexpected explosive combustion can be caused. However, since on the catalyst used in the NOx reduction process of the present invention metal ions

having low activity for hydrocarbon oxidation is highly dispersed for a long time, the catalytic selectivity hardly drops in exhaust gas with high oxygen concentration.

Exhaust gas may also contain other components, such as H₂O, CO₂, CO, H₂ and SO_x. The NO_x reduction process of the present invention is particularly suitable for use in exhaust gas containing water vapor, SO_x and other substances considered to hamper the reaction for selective catalytic reduction using hydrocarbons. The process of this invention is also suitable for removing NO_x from exhaust gas produced by combustion of natural gas in which hydrocarbons having four or fewer carbons account for 90% or more of the entire hydrocarbons calculated in terms of methane. The catalyst using B-substituted BEA zeolite is particularly suitable for reducing NO_x in exhaust gases, such as those generated by combustion of natural gas, in which methane amounts to 50% or more of the entire hydrocarbons.

Since the NO_x reduction process of the present invention uses hydrocarbons to remove NO_x, hydrocarbons in the exhaust gas are also removed, but CO is not removed. An oxidation catalyst may be installed downstream of the catalyst of the present invention, if necessary, to oxidize remaining CO, hydrocarbons etc.

Examples

The present invention will be described further in detail with reference to examples. These examples are not intended to limit the scope of the present invention.

Example 1

According to the method disclosed in the US Patent No. 3,308,069, a solid was crystallized to have a $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 40 by mixing sodium aluminate, sodium hydrate, silica sol, tetraethylammonium hydrate, and water with agitation followed by heating the mixture in an autoclave at 160 °C for 20 hours. The obtained solid was separated, washed with water, dried at 150 °C, and calcined at 550 °C for 5 hours. The obtained BEA aluminosilicate (hereinafter referred to as BEA zeolite) had a $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 44.08. The average diameter of the primary particle of the zeolite crystal was about 0.05 μm , and the primary particles agglomerated to form secondary particles of about 0.6 μm in diameter.

Twelve grams of the obtained BEA zeolite (proton form) was suspended in 65 ml aqueous solution of 0.2 M cobalt acetate, to carry out ion exchange for 5 hours at 60 °C. The resultant ion-exchanged BEA zeolite was separated, washed with water, and then underwent ion exchange again in the same way. The resultant ion-exchanged Co-zeolite was washed with water, dried, and calcined for 5 hours in air at 550 °C, to obtain Co-BEA(1) catalyst. The Co content of this catalyst was 2.22 wt%, the Co/Al ratio was 0.55, and the ion exchange rate was 110%.

Example 2

BEA zeolite with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 18.87 was prepared by the method disclosed in the U.S. Patent No. 3,308,069. The average diameter of the primary particle of the zeolite crystal was about 0.1 μm , and the primary particles agglomerated to form secondary particles of about 0.3 to 0.6 μm in diameter. Using the obtained

BEA zeolite (proton form), Co-BEA(2) catalyst was obtained by the same method as in Example 1, except that 13.03g of the BEA zeolite was suspended in 180 ml aqueous solution dissolving 2g cobalt acetate ($\text{Co}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$). The Co content of Co-BEA(2) catalyst was 4.01 wt%, the Co/Al ratio was 0.54, and the ion exchange rate was 108%.

Example 3

MEL aluminosilicate (hereinafter referred to as MEL zeolite) with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 36.3 was prepared by the method disclosed in the U.S. Patent No. 3,709,979. The average diameter of the primary particle of the zeolite crystal was about 0.05 μm , and the primary particles agglomerated to form secondary particles of about 0.2 to 1.3 μm in diameter. Using the obtained MEL zeolite (Na-form), Co-MEL catalyst was obtained by the same method as in Example 1, except that 15g of the MEL zeolite was suspended in 105 ml aqueous solution of cobalt acetate. The Co content of this catalyst was 2.78 wt%, the Co/Al ratio was 0.56, and the ion exchange rate was 112%.

Example 4

BEA zeolite with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 22.3 was prepared by the method disclosed in the U.S. Patent No. 3,308,069. The average diameter of the primary particle of the zeolite crystal was about 0.05 μm , and the primary particles agglomerated to form secondary particles of about 0.2 to 0.6 μm in diameter. Using the obtained BEA zeolite (Na form), (Co-BEA (3) catalyst was prepared by the same method as in Example 1, except that 250.14g of the BEA zeolite) was suspended in 2 liters of aqueous solution

of 0.2 M cobalt acetate. The Co content of the resultant catalyst was 3.0 wt%, and the Co/Al ratio was 0.40.

Comparative Example 1

Using FAU aluminosilicate (hereinafter referred to as FAU zeolite) with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 4.8, manufactured by UC company, Co-Y catalyst was obtained by the same method as in Example 1, except that 30g of the FAU zeolite was suspended in 500 ml aqueous solution of cobalt acetate. The Co content of this catalyst was 8.2 wt%, the Co/Al ratio was 0.32, and the ion exchange rate was 64%.

Comparative Example 2

Using MOR aluminosilicate (hereinafter referred to as MOR zeolite) with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 11.2, manufactured by Norton company, Co-MOR(1) catalyst was obtained by the same method as in Example 1, except that 5 g of the MOR zeolite was suspended in 500 ml aqueous solution of 0.03 M cobalt acetate, and that the ion exchange operation was repeated four cycles. The Co content of this catalyst was 5.2 wt%, the Co/Al ratio was 0.37, and the ion exchange rate was 74%.

Comparative Example 3

MFI aluminosilicate (hereinafter referred to as MFI zeolite) with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 35 was prepared by the method disclosed in the U.K. Patent No. 1,402,981. Using this MFI zeolite (Na-form), Co-MFI(1) catalyst was obtained by the same method as in Example 1, except that 20g of the MFI zeolite was suspended in 150 ml aqueous solution of cobalt acetate. The Co content of this catalyst was 1.42 wt%, the Co/Al ratio was 0.29, and the ion

exchange rate was 58%.

Example 5

Each of the catalysts obtained in Examples 1 through 3 and Comparative Examples 1 through 3 was formed into a pellet, which was crushed and sieved to obtain 1 to 2 mm particles. The particles were then calcined for 9 hours at 500 °C to prepare sample. Four milliliters of this sample was packed in a stainless steel reaction tube (14 mm in inside diameter). While test gas of the composition specified in Table 1 was allowed to flow at the rate of 1 liter/min (GHSV = 15,000) through this reaction tube, the gas composition at the outlet of the reaction tube was measured by a chemiluminescence NOx meter and by a gas chromatograph.

Table 1

NO	=	500 ppm	H ₂	=	660 ppm
C ₃ H ₈	=	1,000 ppm	CO ₂	=	6 %
O ₂	=	10 %	H ₂ O	=	9 %
CO	=	1,000 ppm	He	=	balance

Table 2 gives the catalytic activity (NOx and propane conversions) of each catalyst at 400 °C and 500 °C. The NOx and propane conversions were calculated from the NOx and propane concentrations at the inlet and outlet of the reaction tube, using the following equations:

$$\text{NOx Conv. (\%)} = \frac{\text{Outlet N}_2 \text{ Conc. (ppm)} \times 2}{\text{Inlet NO Conc. (ppm)}} \times 100$$

$$\text{C}_3\text{H}_8 \text{ Conv. (\%)} = \frac{\text{Inlet C}_3\text{H}_8 - \text{Outlet C}_3\text{H}_8 \text{ Conc. (ppm)}}{\text{Inlet C}_3\text{H}_8 \text{ Conc. (ppm)}} \times 100$$

Table 2

Catalyst	NOx Conversion (C ₃ H ₈ Conversion) (%)	
	400 °C	500 °C
Co-BEA(1)	83.4 (99.8)	73.4 (100)
Co-BEA(2)	80.4 (100)	64.7 (100)
Co-MEL	77.7 (90.5)	65.9 (100)
Co-Y	0 (1.9)	3.9 (51.2)
Co-MOR(1)	54.2 (91.1)	35.4 (100)
Co-MFI(1)	56.8 (94.1)	46.6 (100)

As is clear from Table 2, the Co-BEA(1), Co-BEA(2) and Co-MEL catalysts according to the present invention have high NOx conversions at 400 °C, indicating that they have high activity at low temperature. Their NOx conversions drop only little at 500 °C, which verifies that these catalysts maintain high selectivity for NOx reduction even at high temperatures.

Example 6

Ti-substituted BEA zeolite (hereinafter referred to as "Ti/BEA zeolite") was prepared by the process disclosed in Spanish Patent No. 2,037,596, using tetraethyl orthotitanate as Ti source. The SiO₂/TiO₂ and SiO₂/Al₂O₃ ratios of the starting mixture were 100 and 50, respectively. Specifically, after the mixture for reaction was stirred at 130 °C for 20 days, it was filtrated, washed, dried at 150 °C, and calcined at 550 °C in air. X-ray diffraction analysis revealed that the resultant zeolite is BEA type structure with high crystallinity.

Twenty grams of Ti/BEA zeolite (Na form) thus obtained was

suspended in 300 ml aqueous solution dissolving 2 g cobalt acetate ($\text{Co}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$), to perform ion exchange for 5 hours at 50 °C. After filtration and washing with water, the same ion exchange operation was repeated again. Ion-exchanged zeolite thus
5 obtained was then washed with water, dried, and calcined for 5 hours in air at 550 °C, to give Co-Ti/BEA catalyst. The $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{SiO}_2/\text{TiO}_2$ ratios of this catalyst were 43.6 and 98.27, respectively, the Co content was 1.76 wt%, and the Co/Al ratio was 0.50.

10 Example 7

B-substituted BEA zeolite (hereinafter referred to as "B/BEA zeolite") was prepared by the process disclosed in U.S. Patent Publication No. 5110570, using boric acid as B source. The $\text{SiO}_2/\text{B}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios of the starting mixture were 25
15 and 30, respectively. After the mixture for reaction was stirred at 170 °C for 4 days, it was filtrated, washed, dried at 150 °C, and calcined in air at 550 °C. X-ray diffraction analysis revealed that the resultant zeolite has BEA type structure. The $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio was 437.6.

20 From 20 g of this B/BEA zeolite (proton form), Co-B/BEA (1) catalyst was obtained by the same method as in Example 1, except that the zeolite was suspended in 130 ml aqueous solution of 0.2 M cobalt acetate and that ion exchange operation was repeated three times. The $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of the resultant catalyst was
25 28.96, the Co content was 2.73 wt%, and the Co/Al ratio was 0.49.

 Example 8

B-substituted BEA zeolite was prepared by the process disclosed in U.S. Patent No. 5,110,570, using boric acid as B source. The $\text{SiO}_2/\text{B}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios of the starting mixture were 50 and 28, respectively. After the mixture for
5 reaction was stirred at 175 °C for 4 days, it was filtrated, washed, dried at 120 °C, and calcined in air at 550 °C. X-ray diffraction analysis revealed that the resultant zeolite has BEA type structure. The $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio was 136.7.

The obtained B/BEA zeolite (Na form) (24.4g) was suspended
10 in 200 ml aqueous solution dissolving 4.36 g cobalt acetate, to perform ion exchange for 5 hours at 60 °C. After filtration and washing, the same ion exchange operation was repeated again. Ion-exchanged zeolite thus obtained was then washed with water, dried, and calcined for 5 hours in air at 550 °C, to obtain
15 Co-B/BEA (2) catalyst. The $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of this catalyst was 27.6, the Co content was 2.64 wt%, and the Co/Al ratio was 0.50.

Comparative Example 4

BEA borosilicate was prepared by the process disclosed in U.S. Patent No. 5,110,570, using boric acid as B source. The
20 $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio of the starting mixture was 5. After the mixture for reaction was stirred at 150 °C for 2 days, it was filtrated, washed, dried at 120 °C, and calcined in air at 550 °C. X-ray diffraction analysis revealed that the resultant borosilicate has BEA type structure. The $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio was 23.9.

25 From 12 g of this BEA borosilicate (Na form), Co-BSI catalyst was obtained by the same method of ion exchange and

subsequent operation as in Example 8, except that the borosilicate was suspended in 100 ml aqueous solution of 0.2 M cobalt acetate. The $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio of the resultant catalyst was 40, the Co content was 2.31 wt%, and the Co/B ratio was 0.52.

5 Example 9

For each of the catalysts obtained in Examples 6 and 7, and Comparative Example 4 and Examples 1 and 4, the NO_x selective reduction activity was evaluated by the same method as in Example 5, except that test gas of the composition given in Table 3 was used. The results are shown in Table 4

Table 3

NO	=	150 ppm	H ₂	=	660 ppm
C ₃ H ₈	=	500 ppm	CO ₂	=	6 %
O ₂	=	10 %	H ₂ O	=	9 %
CO	=	1000 ppm	He	=	balance

Table 4

Catalyst	SiO ₂	Co	NO _x Conversion (C ₃ H ₈ Conversion) (%)			
	Al ₂ O ₃	Al	350 °C	400 °C	450 °C	500 °C
Co-Ti/BEA	43.60	0.50	57.9(78.6)	65.6(97.2)	78.5(99.6)	69.5(100)
Co-BEA(1)	44.08	0.55	28.2(28.0)	60.7(60.8)	72.0(79.4)	73.4(97.2)
Co-BSI	(40)*	(0.52)*		5.0(22.8)		2.0(39.5)
Co-B/BEA(1)	28.96	0.49	74.3(98.4)	81.0(99.4)	75.6(100)	58.4(100)
Co-BEA(3)	22.3	0.40	34.8(60.1)	69.5(78.7)	70.8(84.6)	74.5(97.0)

*The values are over B₂O₃ or B. Al is not contained.

As is clear from Table 4, the Co-Ti/BEA and Co-B/BEA (1) catalysts according to another part of the present invention provide higher NO_x conversion than the corresponding Co-BEA (1)

and Co-BEA (3) catalysts in a low temperature range from 350 to 450 °C. That is, even at low temperature and with low NO_x concentration, the former two catalysts provide high NO_x reduction activity due to the substitution by Ti and/or B in the framework. Meanwhile, the Co-borosilicate catalyst without Al cannot support Co ions as dispersed satisfactorily, and therefore provides only little catalytic activity, despite the BEA crystal structure, because boron was removed during ion exchange and borosilicate does not have a stable ion exchange capacity. This finding indicates that Al is vital to a NO_x reducing catalyst for boron-substituted crystalline silicate.

Comparative Example 5

Co-MOR(2) catalyst was obtained by almost the same process as in Example 1, except that 15 g of the same MOR zeolite as in Comparative Example 2 was suspended in 110 ml aqueous solution of 0.2 M cobalt acetate. The Co content of the resultant catalyst was 4.41 wt%, and the Co/Al ratio was 0.36.

Comparative Example 6

MFI (ZSM-5) zeolite with SiO₂/Al₂O₃ ratio of 50 was prepared by the process disclosed in British Patent No. 1,402,981. Ten grams of this MFI zeolite (Na form) was suspended in 1 liter aqueous solution of 0.0073 M cobalt nitrate, to perform ion exchange at 40 °C for 24 hours then at 80 °C. The resultant zeolite was filtrated, washed with water, dried, and calcined at 500 °C for 5 hours, to obtain Co-MFI(2) catalyst. The Co content of this catalyst was 1.9 wt%, and the Co/Al ratio was 0.53.

Example 10

For each of the catalysts obtained in Example 8 and Comparative Examples 5 and 6, the NO_x selective reduction activity was evaluated by the same method as in Example 5, except that test gas of the composition given in Table 5 was used.

Table 5

NO	=	500 ppm	H ₂	=	660 ppm
CH ₄	=	2000 ppm	CO ₂	=	6 %
O ₂	=	10 %	H ₂ O	=	0 % or 9 %
CO	=	1000 ppm	He	=	balance

Table 6 gives the evaluation result of catalytic activity. The CH₄ conversion was calculated by the same method as for C₃H₈ conversion. A reference result of boron-free catalyst (Co-BEA(Ref.); Example 13 in Japanese Patent application laid-open No. Hei 07-513125) under the same conditions is also shown in Table 6.

Table 6

Catalyst	NO _x Conversion (CH ₄ Conversion) (%)			
	H ₂ O = 0%		H ₂ O = 9%	
	400 °C	500 °C	400 °C	500 °C
Co-B/BEA(2)	44.4(24.8)	34.1(93.9)	3.5(1.0)	30.9(48.9)
Co-MOR(2)	56.1(27.8)	51.7(91.4)	0 (0.9)	4.4(12.3)
Co-MFI(2)	25.2(13.3)	31.0(75.0)	0 (2.4)	0 (12.7)
Co-BEA(Ref.)			0 (3.0)	7.5(26.9)

As is clear from Table 6, Co-MOR(2) and Co-MFI(2) catalysts disclosed in U.S. Patent Publication No. 5,149,512 provide high NO_x conversion in the absence of water vapor, but are substantially deactivated in the presence of water vapor. By

contrast, Co-B/BEA (2) catalyst of the present invention is highly active even in the presence of water vapor, obviously more active than Co-BEA (Ref.) catalyst which is not substituted with B.

5 Example 11

BEA zeolite (Na form) with $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 19.7 was prepared by the method disclosed in the U.S. Patent No. 3,308,069. Using this BEA zeolite, Co-BEA(4) catalyst was obtained by the same method as in Example 1, except that 15g of
10 the BEA zeolite was suspended in 60 ml aqueous solution of cobalt acetate. The Co content of this catalyst was 1.82 wt%, the Co/Al ratio was 0.21, and the ion exchange rate was 42%.

The activity evaluation of this catalyst, conducted by the same method as in Example 5, showed that the NOx conversion at
15 400 °C was 66%. The durability of this catalyst was also evaluated by the same method as in Example 5, except that the test was carried out by continuous flowing of the gas of the composition specified in Table 7 which simulates the exhaust of a lean burn natural gas engine. Fig. 1 shows the result of
20 evaluation. The NOx and C_3H_8 conversions were calculated by the same method as in Example 5.

Table 7

25	NO	=	150 ppm	H ₂	=	250 ppm
	C ₃ H ₈	=	500 ppm	CO ₂	=	6 %
	O ₂	=	10 %	H ₂ O	=	9 %
	CH ₄	=	1000 ppm	SO ₂	=	0.3 ppm
30	CO	=	500 ppm	He	=	balance

As is obvious from Fig. 1, the Co-BEA (4) catalyst constantly maintained 60% or higher NOx conversion rate for 2,000 hours, verifying that the catalyst of the present invention not only provides high initial activity but high durability even in an atmosphere containing water vapor and SOx.

Example 12

The durability of Co-MEL catalyst of Example 3 was evaluated by the same method as in Example 11. The catalyst was stable in activity and had about 50% NOx conversion rate even after the lapse of 500 hours.

Comparative Example 7

The durability of Co-MOR(1) catalyst of Comparative Example 2 was evaluated by the same method as in Example 11. In 24 hours, the catalytic activity deteriorated substantially, with the NOx conversion dropping below 20%. Therefore, the operating temperature was raised to 450 °C. Although the conversion rate recovered temporarily, it soon resumed declining trend, dropping below 10% in 140 hours. Thus, the Co-MOR(1) catalyst is not durable enough for practical use.

Comparative Example 8

Co-MFI(3) catalyst ($\text{SiO}_2/\text{Al}_2\text{O}_3 = 50$) was obtained by almost the same method as in Comparative Example 3. The Co content was 1.9 wt%, the Co/Al ratio was 0.53, and the ion exchange rate was 106%.

Activity evaluation of the Co-MFI (3), conducted by the same method as in Example 5, showed that the catalyst had 68% NOx conversion rate at 400 °C. The durability was also evaluated by

the same method as in Example 11. Fig. 2 shows the result of the evaluation. The catalytic activity deteriorated substantially with time, and the NO_x conversion dropped below 20% in 500 hours. These evaluation results indicate that the Co-MFI(3) catalyst is not sufficiently durable in an actual operating atmosphere although its initial activity is moderately high.

Comparative Example 9

Five grams of BEA zeolite (proton-form) with SiO₂/Al₂O₃ ratio of 22.3 was suspended in 1,000 ml aqueous solution of 0.0035 M copper acetate, to carry out ion exchange for 18 hours at room temperature. The resultant ion-exchanged Cu-BEA zeolite was washed with water, dried, and calcined for 9 hours at 500 °C, to give Cu-BEA catalyst. The Cu content of this catalyst was 4.0 wt%, the Cu/Al ratio was 0.53, and the ion exchange rate was 107%.

The durability of this catalyst was evaluated by the same method as in Example 11, except that the operating temperature was 500 °C. Fig. 3 shows the result of evaluation. As shown, this catalyst provides poor selectivity for NO_x reduction, and the activity continues declining even after the lapse of 600 hours. This activity deterioration is presumably caused by aggregation of Cu ions as in the case with the Cu-ZSM-5 (Cu-MFI) catalyst, also reported by the inventors ("Study on Surface Science and Catalysis," Vol. 88, p. 409). Thus, if ion-exchanged with Cu, the BEA catalyst cannot have higher NO_x conversion or higher suppression effect on Cu ion aggregation than does the MFI catalyst.

Example 13

The durability of the Co-BEA (3) catalyst obtained in Example 4 was evaluated by the same method as in Example 11, except that, as test gas, the exhaust gas of the average composition specified in Table 8, discharged from a natural gas-fueled cogeneration system (air/fuel ratio = approx. 1.4), to which 1,000 ppm C₃H₈ was added, was allowed to flow at the rate of 10 liter/min (GHSV = 15,000) at 450 °C through the reaction tube packed with 40 ml of the catalyst sample. Fig. 4 shows the result of evaluation.

Table 8

NO	=	ca. 500 ppm	CO	=	ca. 800 ppm
THC	=	ca. 2200 ppm (including CH ₄)		=	ca. 1600 ppm
CO ₂	=	ca. 8.5 %	SO ₂	=	ca. 0.4 ppm
O ₂	=	ca. 6 %	H ₂ O	=	ca. 13 %

As is clear from Fig. 4, even in actual engine exhaust gas, this catalyst showed 60% or higher NO_x conversion for 1,500 hours, with slight variation due to fluctuation in the air/fuel ratio of the combustion in the engine.

EFFECT OF THE INVENTION

According to the present invention, since the catalyst carries a metal with low activity for hydrocarbon oxidation, it provides high selectivity for NOx reduction. In addition, the catalyst of this invention uses a crystalline metallosilicate support on which metal ions can be loaded with high dispersion. Furthermore, straight channels of large section, oriented in two or more different dimensional directions and communicating with each other, are formed in this crystalline metallosilicate support, enabling reactants to be diffused at a very high rate. Consequently, the catalyst can effectively use metal ions (active sites) existing deep in the straight channels, so is highly active in NOx reduction even at low temperatures. Since the NOx reduction process according to the present invention uses the above-mentioned catalyst, it effects high NOx conversion in a wide range of temperatures and even in an atmosphere unfavorable to diffusion in channels, such as an atmosphere of low NOx concentration or containing water vapor, SOx and other substances detrimental to the reaction. The B-substituted catalyst in particular is capable of selective NOx reduction by methane in the presence of water vapor.

CLAIMS

1. A catalyst for reducing nitrogen oxides (NOx) with hydrocarbons in an oxygen-rich atmosphere, comprising crystalline
5 metallosilicate ion-exchanged with Co, said crystalline metallosilicate having straight channels of oxygen 8-ring or larger section oriented in at least two different dimensional directions, said straight channels communicating with each other via oxygen 8-ring or larger micropores, the straight channels in
10 at least one of said at least two different dimensional directions having oxygen 10-ring or larger section.

2. The NOx reducing catalyst according to Claim 1, wherein the crystalline metallosilicate has the average diameter of the primary particles of 0.01 to 0.2 μm .

15 3. The NOx reducing catalyst according to Claim 1, wherein the crystalline metallosilicate is aluminosilicate.

4. The NOx reducing catalyst according to Claim 3, wherein the crystalline metallosilicate is of BEA type.

20 5. The NOx reducing catalyst according to Claim 4, wherein the crystalline metallosilicate is crystalline aluminosilicate with an $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 10 to 100 and with a Co/Al ratio of 0.2 to 0.6.

25 6. The NOx reducing catalyst according to Claim 5, wherein a part of Si is substituted by Ti, and/or a part of Al substituted by B in the crystalline metallosilicate.

7. The NOx reducing catalyst according to Claim 6, wherein an $\text{SiO}_2/\text{TiO}_2$ ratio is between 20 and 200.

8. The NOx reducing catalyst according to Claim 6 wherein an $\text{SiO}_2/\text{B}_2\text{O}_3$ ratio before ion exchange is between 20 and 500.

9. A process for reducing NOx in exhaust gas which contains hydrocarbons and excessive amount of oxygen by hydrocarbons having two or larger number of carbons, comprising the step of: using a catalyst which contains at least crystalline metallosilicate ion-exchanged with Co, said crystalline metallosilicate having straight channels of oxygen 8-ring or larger section oriented in at least two different dimensional directions, said straight channels communicating with each other via oxygen 8-ring or larger micropores, the straight channels in at least one of said at least two different directions having oxygen 10-ring or larger section.

10. The process for reducing NOx according to Claim 9, wherein the catalyst essentially consists of the crystalline metallosilicate, being BEA type aluminosilicate with an $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of 10 to 100 and ion-exchanged with Co to have a Co/Al ratio between 0.2 and 0.6.

11. The process for reducing NOx according to Claim 9, wherein the catalyst essentially consists of BEA type aluminosilicate in which a part of Si is substituted by Ti, and/or a part of Al substituted by B, and which is ion-exchanged with Co to have a Co/Al ratio between 0.2 and 0.6.

12. The process for reducing NOx according to Claim 11, wherein the catalyst essentially consists of BEA type aluminosilicate with an $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio between 10 and 100 and with an $\text{SiO}_2/\text{TiO}_2$ ratio between 20 and 200.

13. The process for reducing NO_x according to any one of Claims 9 to 12, wherein 90% or more of the hydrocarbons calculated in terms of methane contained in the exhaust gas are hydrocarbons having four or smaller number of carbons.

5 14. A process for reducing NO_x by hydrocarbons in exhaust gas containing excessive amount of oxygen and hydrocarbons in which 50% or more of hydrocarbons calculated in terms of methane are methane, comprising: using a catalyst which at least contains
10 BEA type aluminosilicate with an SiO₂/Al₂O₃ ratio between 10 and 100 and with an SiO₂/B₂O₃ ratio before ion exchange between 20 and 500, and ion-exchanged with Co to have a Co/Al ratio between 0.2 and 0.6.

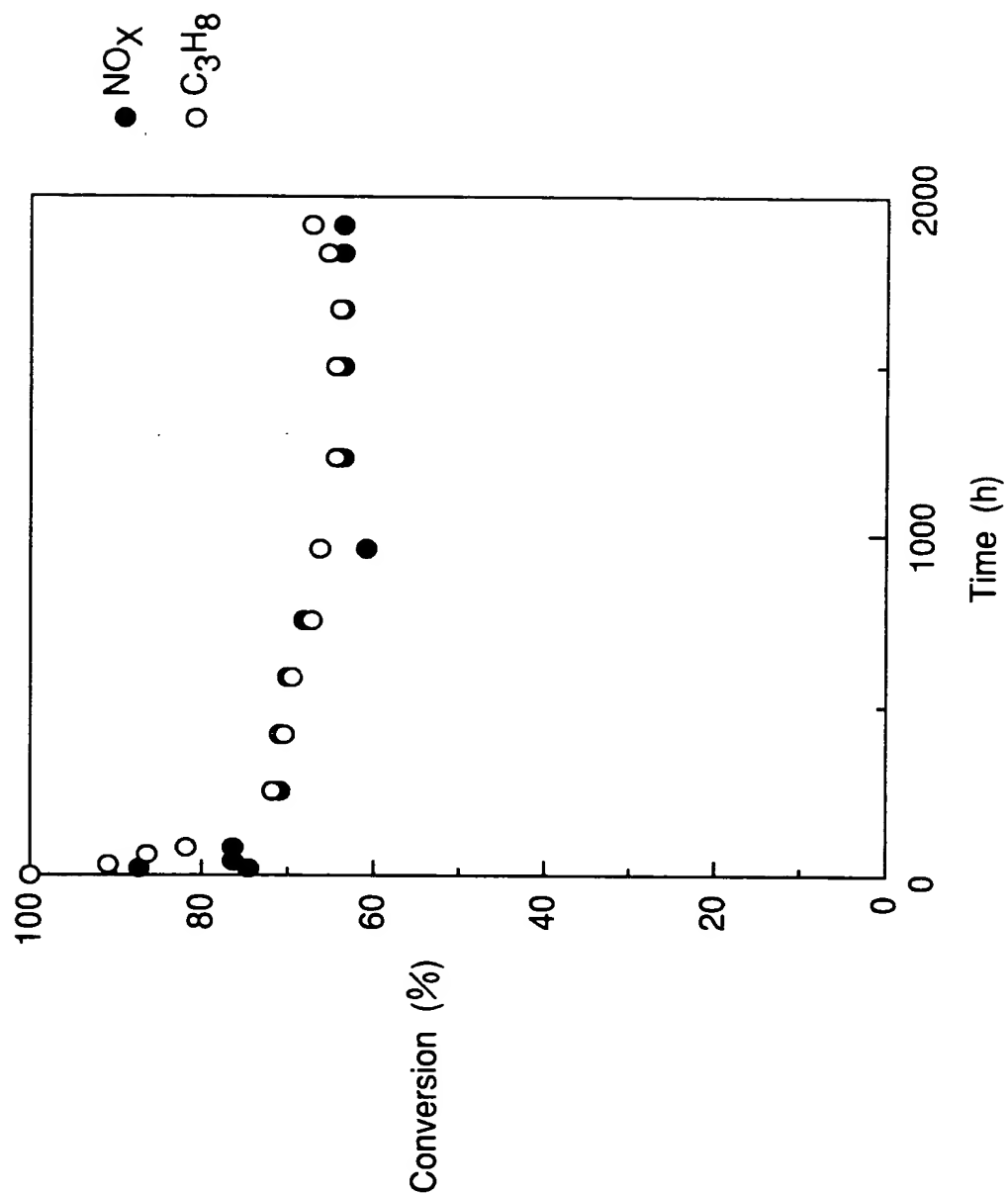


Fig.1

Fig.2

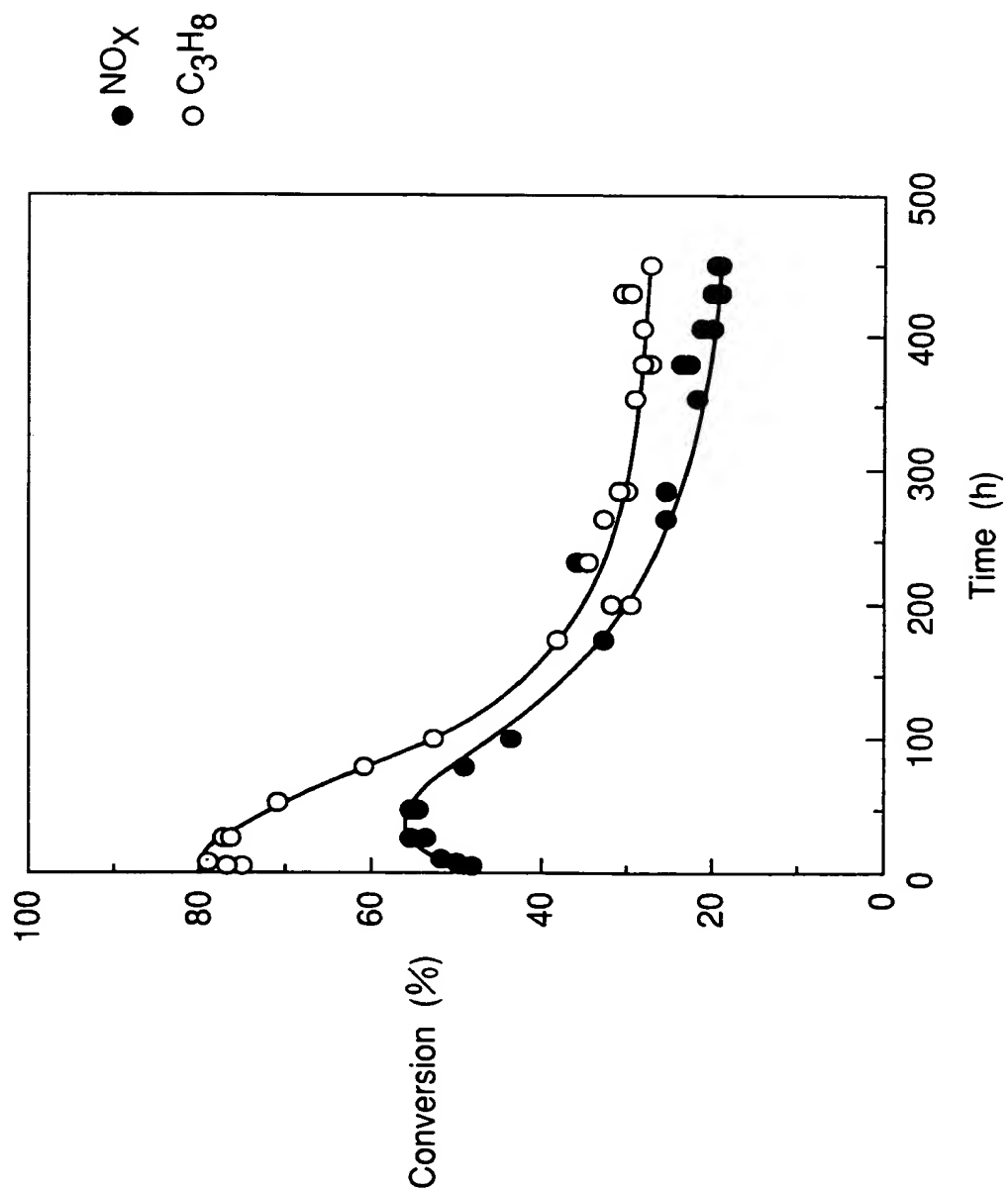
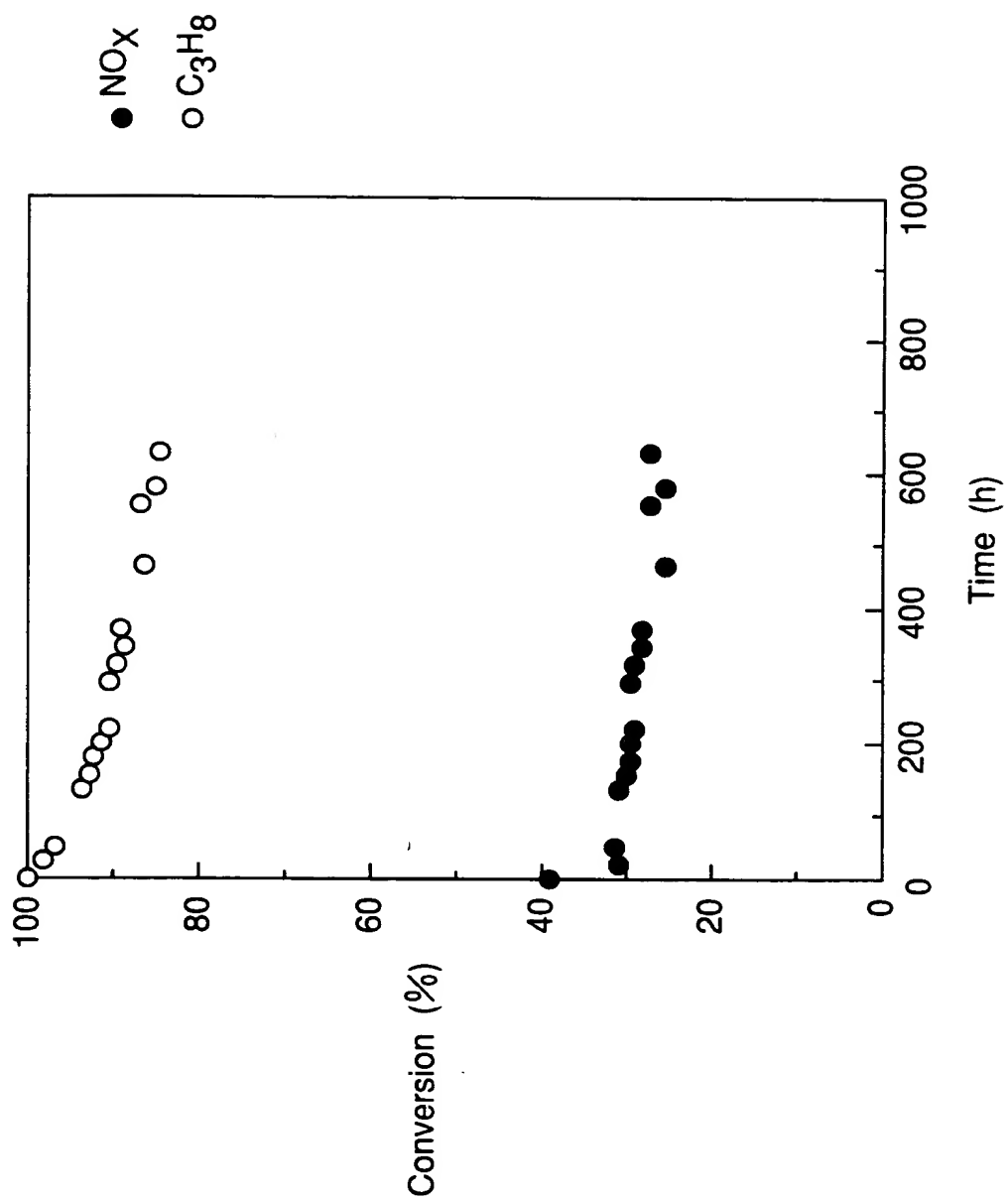


Fig.3



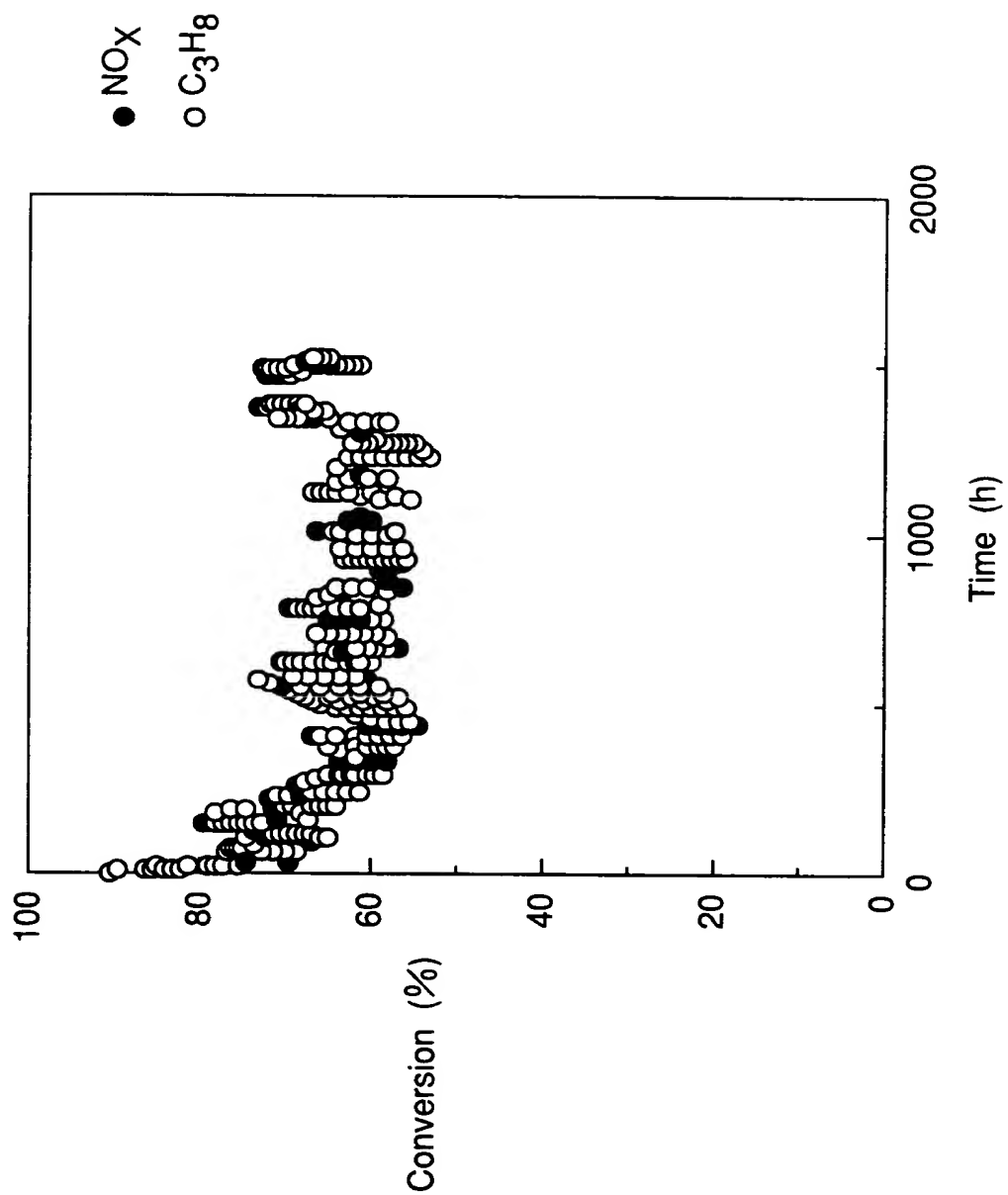


Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 96/00637

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01D53/86 B01D53/94 B01J29/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01D B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	EP,A,0 652 040 (ENIRICERCHE & OSAKA GAS) 10 May 1995 see page 3, line 11 - page 4, line 15; claims; examples	1-5,9, 10,13
X	WO,A,94 01365 (MOBIL OIL CORPORATION) 20 January 1994 see claims	1,3,4,9
A		5,6, 10-14
X	US,A,5 149 512 (AIR PRODUCTS AND CHEMICALS) 22 September 1992 cited in the application see claims 1-6; table 2	1,3,4,9, 13
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
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- *P* document published prior to the international filing date but later than the priority date claimed

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- *&* document member of the same patent family

Date of the actual completion of the international search

26 June 1996

Date of mailing of the international search report

08 -07- 1996

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP 96/00637

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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PCT/JP 96/00637

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